MULTI-MODE TRANSPONDER RECEIVER ARCHITECTURE

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a multi-mode radio frequency (RF) receiver architecture.

Discussion of the Known Art

The ability to distinguish reliably between friendly and hostile approaching aircraft, is extremely important. So-called identification-friend-from-foe (IFF) systems, e.g., the Mark X IFF system, employ a single interrogation frequency (1,030 MHz) and a single reply frequency (1,090 MHz) with a standard reply code. Three coded interrogations, designated Modes 1, 2 and 3 can be selected, wherein each interrogation has a pulse spacing of 3, 5 or 8 μsec corresponding in order to the selected mode.

An airborne transponder replies with a single pulse for Modes 1 and 3, and a pulse-pair with 16 µsec spacing for Mode 2. A coder unit enables variable coded replies to be generated providing a Special Identity Feature (SIF), thus allowing a ground controller quickly to determine a particular aircraft's designation or function. Mark X SIF/IFF systems have been used in most military aircraft since 1959, and the system also serves as an aid to civil air traffic control as part of the Air Traffic Control Radar Beacon System (ATCRBS). Transponders used on civil aircraft use Mode 3 IFF, with the Mode designation "3/A" to connote common military/civil usage.

Present "Mark XII" systems operate in Modes 1, 2, 3/A, 4 and C, all of which use defined patterns of pulse amplitude modulation (PAM). Also specified are Mode S that uses phase shift keying (PSK) modulation, and Mode 5 using spread spectrum modulation over a relatively wide bandwidth (typically 16 MHz) that is greater than the data rate.

As mentioned, current IFF systems call for transponder receivers to operate at a single center frequency of 1,030 MHz. Since 1981, a Joint Tactical Information Distribution System (JTIDS), also known as the Multi-Functional Information Distribution System (MIDS), provides military forces with both

communications and navigation functions for deployment on aircraft and ships. MIDS operates on 51 frequencies in a 960 to 1215 MHz band. Because MIDS signals employ spread spectrum modulation (frequency hopping and phase coding) techniques, they represent potential interfering signals to IFF transponders having receivers tuned at 1,030 MHz, notwithstanding the two closest MIDS frequencies are each 22 MHz away from 1,030 MHz, i.e., at 1,008 MHz and at 1,052 MHz.

Specifically, since emitted MIDS signals use spread spectrum modulation, broadband noise generated by a MIDS transmitter may be within the passband of an IFF transponder receiver. To meet this problem, transponder receivers have incorporated both narrow band RF preselectors and narrow band intermediate frequency (IF) channels to achieve reliable interrogation signal detection in the presence of MIDS signal interference. But certain performance parameters such as pulse fidelity, phase distortion, inter-symbol interference and receiver group delay have been compromised, however. And, while a narrow band receiver front end may allow Mark XII and Mode S interrogating signal waveforms to be detected reliably while rejecting MIDS signal interference, such an approach is incompatible with Mode 5 IFF spread spectrum applications which require a much larger receiver bandwidth for full processing

gain. The spread spectrum nature of Mode 5 does, however, make those emissions less susceptible to noise produced by unrelated MIDS signals transmissions.

Accordingly, there is a need for a transponder receiver that can detect and process both wide and narrow band interrogation mode signals reliably in the presence of potential interference, wherein the processing of the wide band mode signals is not compromised by portions of the receiver that are used for processing of the narrow band mode signals.

SUMMARY OF THE INVENTION

According to the invention, a transponder receiver for detecting different radio frequency (RF) interrogation mode signals having relatively wide and narrow bandwidths about a common RF center or carrier frequency, includes a front end stage adapted to connect with an antenna responsive to the different interrogation mode signals, a preselector for amplifying the signals input by the antenna and including a wide band RF filter having a pass band sufficient to pass both the wide and the narrow bandwidth interrogation mode signals about the RF center frequency, and a mixer for converting signals output by the

preselector to frequencies within an intermediate frequency (IF) band. A first IF channel coupled to the front end stage has a narrow band IF filter with a pass band sufficiently wide to pass first IF signals corresponding to the narrow bandwidth interrogation mode signals, but to reject signals corresponding to undesired interfering signals at frequencies in the vicinity of the narrow bandwidth interrogation mode signals. A second IF channel coupled to the front end stage has a wide band IF filter with a pass band sufficiently wide to pass second IF signals corresponding to the desired wide bandwidth interrogation mode signals.

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According to another aspect of the invention, a multi-mode receiver for detecting desired radio frequency (RF) signals having relatively wide and narrow bandwidths about a common RF center or carrier frequency, includes a front end stage having an input adapted to connect with an antenna responsive to the desired RF signals, a preselector for amplifying the signals input by the antenna and having a wide band RF filter with a pass band sufficient to pass both of the desired wide and narrow bandwidth signals about the center RF frequency, and a mixer for converting signals output by the preselector to frequencies within an intermediate frequency (IF) band.

A first IF channel coupled to an output of the front end stage has a narrow band IF filter with a pass-band of sufficient width to pass first IF signals corresponding to the desired narrow bandwidth signals, but to reject signals corresponding to undesired interfering signals at frequencies in the vicinity of the desired narrow bandwidth signals. A second IF channel coupled to an output of the front end stage has a wide band IF filter with a pass band of sufficient width to pass second IF signals corresponding to the desired wide bandwidth signals.

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For a better understanding of the invention, reference is made to the following description taken in conjunction with the accompanying drawing and the appended claims.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIG. 1 is a schematic block diagram of an IFF transponder including receivers according to the invention;

FIG. 2 is an overall block diagram of one of the receivers in the transponder of FIG. 1;

FIG. 3 is a schematic block diagram of a front end stage in the receiver of FIG. 2;

FIG. 4 is a schematic block diagram of a first intermediate frequency (IF) channel in the receiver of FIG. 2; and

FIG. 5 is a schematic block diagram of a second IF channel in the receiver of FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

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FIG. 1 is a functional block diagram of a transponder 10 including a receiver assembly 12 and a transmitter assembly 14. The receiver assembly 12 includes two substantially identical receivers 20, each with an input terminal 22 adapted for coupling to a separate receiving antenna 24 for diversity performance. For example, a top antenna 24 associated with one of the receivers, and a bottom antenna 26 associated with the other receiver, may be deployed at corresponding top and bottom positions on an aircraft body. Each receiver 20 is configured to respond, for example, to desired Mark XII SIF Modes 1, 2, 3/A, C and Mode 4, as well as to desired Mode S and Mode 5 interrogating signal waveforms. An overall block diagram of one of the receivers 20 is given in FIG. 2.

The receiver assembly 12 also has a modulator 30, which provides frequency generation for each of the receivers, and waveform modulation for the transmitter assembly 14. The transmitter assembly 14 includes a power amplifier 32, and an antenna input-output (I/O) interface 34 including an RF switch 36 coupled between an output of the power amplifier 32 and each of two selectable diplexers 38. Each diplexer 38 is coupled to an associated one of the antennas 24, 26, through a corresponding

bit coupler 39, and each coupler 39 is driven by a bit output of the modulator 30.

As shown in FIG. 3, the antenna input terminal 22 of each receiver 20 is coupled to an input of a front end stage 40. The stage 40 comprises, for example, a first RF amplifier 42 with a first set of input overload limiting diodes 44, and a preselector filter 46 whose input is coupled to an output of first RF amplifier 42 and a second set of overload limiting diodes 48. The first RF amplifier 42 may comprise a low noise (e.g., 2.6 dB noise figure), high dynamic range (IP3 = + 36 dBm) silicon bipolar surface mount MMIC amplifier.

The filter 46 can be, for example, a six-resonator, 8-mm ceramic filter. The number of resonators establishes a desired bandwidth and selectivity, while the resonator size assures low insertion loss. Filter 46 has a pass band centered at 1,030 MHz with typically 65 dB rejection at the nearest MIDS frequencies of 1008 and 1052 MHz. The 3-dB bandwidth of filter 46 is typically 20 MHz, and an output of filter 46 is coupled to an input of a second RF amplifier 50. The characteristics of filter 46 are chosen to ensure that the second RF amplifier 50 will not produce distortion components that may exceed the receiver's thermal noise floor.

The first RF amplifier 42 and filter 46 are dominant in establishing an overall receiver noise figure of about 8 dB maximum. The overall 3-dB bandwidth of the front end 40 is typically about 20 MHz, providing 65 dB rejection to those MIDS signals nearest the receiver's center frequency. An output of the second RF amplifier 50 is coupled to a down-converting mixer 52 within the front end stage 40. The mixer 52 generates a 60 MHz intermediate frequency (IF) band at its output, in response to a 970 MHz local oscillator input signal supplied from the modulator 30.

The output of the mixer 52 is coupled to an IF amplifier 60. The amplifier 60 is typically a low noise, high dynamic range (IP3 = + 26 dBm) operational amplifier. Amplifier 60 also provides a proper terminating impedance for the mixer 52, as well as an optimal source impedance for first and second IF channels 62, 64. Each of the IF channels is coupled at its input to an output of the front end stage 40.

The first IF channel 62, shown in FIG. 4, includes a first IF filter 70. The filter 70 has a typical 3-dB bandwidth of 7.5 MHz, and a rejection of 80 dB at the nearest (converted) MIDS frequencies. The combination of the front end stage 40 and the first IF filter 70 thus provides a total of, e.g., 145 dB

attenuation at the nearest MIDS converted frequencies, and ensures that worst case MIDS RF spectral interference will remain below the receiver's noise floor.

The output of the first IF filter 70 is applied to an input of a log amplifier 72, which has a 72-dB logging range for detection of Mark XII mode, pulsed amplitude modulated interrogation signals. An output of the log amplifier 72 is applied to an input of a signal processor (not shown) through a video filter and buffer amplifier 74.

Down-converted Mode S (DPSK) signals at the output of the first IF filter 70 are applied to an input of a limiter 76 which has, e.g., a 100-dB limiting range. An output of the limiter 76 is down-converted, e.g., by 20 MHz, by a mixer 78 to which an 80 MHz LO signal is applied from the modulator 30. The second down-conversion by 20 MHz enables received Mode S signals to interface easily with an associated signal processor, while still preserving the information bandwidth. The output of the mixer 78 is coupled to the signal processor through a zonal filter 80 and a limiting amplifier 82. The zonal filter 80 serves two purposes. First, it confines the spectral energy of the limited signal, and, second, it provides any needed rejection from the 80 MHz local oscillator that feeds the mixer 78.

The second IF channel 64, shown in FIG. 5, enables the receiver 20 to receive and process the wider band, spread spectrum Mode 5 interrogation signals in the absence of relatively narrow band (e.g., 7-MHz) filtering that is used in the first IF channel 62 to optimize detection of other mode signals. A wide band (typically 18 MHz) filter 90 has its input coupled directly to an output of the 60 MHz IF amplifier 60 in the front end stage. An output of the filter 90 is coupled to a limiter 92, and the wide band filter 90 is configured to reject potential MIDS signal interference sufficiently to prevent the limiter 92 from being captured by a MIDS signal. An output of the limiter 92 supplies down-converted, spread spectrum Mode 5 signals to a digital growth module 94. The module 94 operates to quantize, digitize, and quadrature de-modulate the Mode 5 signals. The de-modulated signals are applied to a bank of digital matched filters for detection, wherein the filters are matched to a defined Mode 5 waveform. Because of this, any detected MIDS signal energy is "spread" over a wide bandwidth effectively reducing MIDS interference even further.

As shown in FIG. 5, the wide band filter 90 may have a second output port which is coupled to the input port of the narrow band filter 70 of the first IF channel 62 in FIG. 4. Such an arrangement may serve to equalize the overall response time of

the transponder 10 to various modes of interrogation signals, regardless of the IF channel through which the signals are detected and demodulated.

The selectivity of the overall receiver 20 is determined by the first RF amplifier 42, filter 46, second RF amplifier 50, and the IF amplifier 60. The front end filter 46 is centered 1030 MHz, with a 3-dB bandwidth of, e.g., 22 MHz and a constant group delay over a 12 MHz bandwidth. The first IF filter 70 is, e.g., a 6-pole lumped element Chebyshev filter centered at 60 MHz with a 3-dB bandwidth of 7.5 MHz, an 80-dB bandwidth of 44 MHz, and ultimate out of band rejection of 85 dB from 5 to 30 MHz and 92 to 300 MHz.

As mentioned, Mode 5 signal information is spread over a bandwidth greater than its data rate, and an overall Mode 5 receiver bandwidth should be greater than 12 MHz to process the Mode 5 waveform efficiently. Prior receiver architectures channeled Mode 5 signals through stages having bandwidths too narrow to realize the full capability of Mode 5. The present receiver architecture allows optimum Mode 5 performance without compromising MIDS signal rejection in any of the receiver operating modes.

While the foregoing description represents preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the invention pointed out by the following claims.